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HAROLD L. ICKES, SECRETARY

BUREAU OF MINES
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INFORMATION CIRCULAR

SAFE STORAGE, HANDLING, AND USE OF COMMERCIAL EXPLOSIVES

BY

D. HARRINGTON

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SAFE STORAGE, HANDLING, AND USE OF COMMERCIAL EXPLOSIVES[1]

By D. Harrington[2]

An explosive may be defined as a substance (usually a mixture) that has the property of yielding readily to combustion or oxidation upon application of flame or shock, the combustion or oxidation process being rapid and accompanied by formation of such relatively large quantities of gases that much violence and pressure are produced; these, in turn, react against their surroundings and cause what is termed an explosion. By their very nature their action is destructive and disruptive of adjacent materials; hence, all explosives are potentially hazardous and every type of explosive, irrespective of its relative safety, should be handled, stored, and used with utmost care at all times and under all conditions. It should always be remembered that any explosive can be made safe only in certain of its features and under certain conditions and circumstances. If these facts (and they certainly are facts) are always kept in mind, most of the modern types of explosives can be utilized advantageously in our industrial life and with a considerable degree of safety. That commercial explosives can be handled safely is borne out in part by the fact that in the past 15 years at least 3,000,000,000 pounds of the commercial explosive dynamite have been transported by railroads in the United States without injury to any person, insofar as available records indicate.

Commercial explosives may be considered to include black blasting powders of various kinds, some smokeless powders for guns used by sportsmen and for other similar purposes, so-called high explosives such as the various dynamites and permissible explosives, and the various kinds of igniters and detonators used to set off both dynamite and black powder. These commercial explosives are distinctly different from military explosives used for war munitions; in general, the two are not at all suitable for interchange, though considerable dynamite is used in military construction work and a small amount of black blasting powder is employed in shells for guns; on the other hand, some of the constituents of military explosives are also used in the manufacture of commercial explosives.

In addition to the well-defined explosives (dynamite, black blasting powder, etc.), there are devices and systems that accomplish results essentially similar to those brought about by the use of explosives by

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2/ Chief, Health and Safety Branch, Bureau of Mines, Washington, D. C.

utilizing the explosive properties of carbon dioxide or other gases under heavy pressures. In their action these devices and methods also are destructive and disruptive of adjacent materials; they are in effect, even if not in name or by exact definition, explosives and should be handled and used with as much care as is the ordinary commercial explosive, such as dynamite, permissible explosive, or black blasting powder. The use of these methods has been limited to coal mining in the United States, and even there the installations are relatively few but appear to be expanding. Liquid oxygen is being utilized to a limited extent in the United States, chiefly in open-pit coal mining, and it has characteristics (including hazards) largely similar to those of the other commercial explosives.

In the United States the annual consumption of dynamite (including permissible explosives, which are modified dynamites used chiefly in coal mining) is between 250,000,000 and 400,000,000 pounds, more than half of which is utilized in mining and quarrying; considerable amounts, however, are employed in agriculture, in engineering projects of various kinds, such as general construction work, dredging rivers and harbors, breaking scrap iron, road making, blasting trenches in rock for drainage, laying pipe lines, etc., in breaking log jams in lumbering, in clearing tree stumps off land, and for scores of other purposes. Between 70,000,000 and 125,000,000 pounds of black blasting powder is used annually in the United States, more than 90 percent of it in mining and quarrying. Approximately 70 percent of the commercial explosives used in the United States are consumed by our mines and quarries (about 38 percent in coal mines, 19 percent in metal mines, and 13 percent in quarries); therefore, it is logical that most of the observations in this paper will discuss conditions in and around mines and quarries with regard to explosives, and these observations will be based largely on the personal ideas and experiences of the writer.

Although most safety men now look upon black blasting powder with disfavor, it is one of the oldest and most generally used explosives in commercial work. It burns with extreme rapidity instead of detonating like high explosives; it is highly sensitive to flame or sparks or friction and gives off much flame, which is hot and of great length and duration; and these properties make it extremely hazardous for use in mines and quarries, especially coal mines. The gases given off in detonation not only are very hot but frequently contain harmful constituents. Notwithstanding its numerous deficiencies, from a safety standpoint, it has action characteristics that make it valuable in both coal mining and quarrying, though it has relatively little utility in metal mining. It is difficult to use it effectively in wet places, this being its main disadvantage from an efficiency standpoint. Pellet powder is black blasting powder in consolidated (pellet or stick) form rather than in grains or granules, and it has few if any real advantages (safety or otherwise) over black blasting powder, notwithstanding the fairly prevalent idea that it is a "safe" explosive.

Smokeless powders have a somewhat different composition from that of black blasting powder and are used chiefly for sportsmen's ammunition and, more widely, for military purposes. They are decidedly sensitive to flame and impact but ordinarily are so packaged that if reasonable judgment is used they are relatively harmless.

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High explosives used in commercial work are the various dynamites, one type of which is the group known as permissible explosives, employed chiefly in coal mining; all high explosives require the use of a detonator or cap to set them off, as against using either igniters or caps to set off black blasting powder. Commercial dynamites usually are composed of some proportion of nitroglycerin absorbed in some other material or "dope", such as wood pulp, sodium nitrate, etc., the differences in the dynamites being achieved by varying the percentage of nitroglycerin, using different "dopes", and introducing other materials either of an explosive nature or for the purpose of cooling or otherwise modifying some feature of the nitroglycerin in or after being fired.

Nitroglycerin itself is a somewhat thick, oily liquid, which is highly explosive and very sensitive to shock, friction, heat, and flame; in other words, it is an extremely hazardous substance to handle and in unmodified form is used relatively little in commercial life, and then chiefly in oil-well operations.

Various types, grades, and strengths of dynamite are available, such as straight nitroglycerin dynamite, ammonia or so-called "extra" dynamite, gelatin dynamite, and ammonia-gelatin dynamite. Each has its own characteristics and is supposedly suitable for certain uses or for use under certain conditions. However, all give off dangerous gases upon detonation, and all are definitely dangerous to use, especially in coal mines, except as modified into what are termed "permissible" explosives. When used in metal mines, the various kinds of dynamite are also hazardous, but if recommended precautionary measures are taken they can be used in metal mining with fair protection of both health and safety of workers. The straight nitroglycerin dynamites ought not be used underground, however, because of their characteristic of emitting dangerous fumes upon detonation. The ammonia or the gelatin dynamites also give off dangerous fumes upon detonation but in much smaller quantity than the straight nitroglycerin types. All dynamites should be fired with a strong detonator (certainly not less strong than a no. 6 cap), and all should be well-confined in the drill hole with incombustible stemming.

Permissible explosives are essentially high explosives (dynamites) modified by the introduction of "dopes", whose function in general is to decrease flame temperature and to a smaller extent, length and duration of flame when the explosive is converted from a solid into gaseous form - in other words, when it is fired or detonated. The designation "permissible" is given to an explosive of modified dynamite type after such explosive has passed certain tests made by the Federal Bureau of Mines; and the permissible character of such explosives depends not only upon the ingredients in the explosive but also on certain well-defined specifications as to handling and use. As with the dynamites, there are several different types, grades, and strengths of permissible explosives, such as ammonium nitrate permissibles, hydrated permissibles, organic nitrate permissibles, nitroglycerin permissibles, ammonium perchlorate permissibles, and gelatin permissibles, but essentially all of those now used to any extent can be placed in either the ammonium nitrate or the gelatin classes.

The ammonium nitrate permissible explosives have relatively little nitroglycerin and relatively large proportions of ammonium nitrate, the latter being itself an explosive substance but one less sensitive to impact, sparks, and flames than nitroglycerin. This type of permissible explosive is now used extensively, as it has a rather wide range of strength, rate of detonation, density, size of cartridge, etc., and can be utilized not only in dry but also to some extent in fairly wet holes if charged carefully and fired promptly after having been placed in the hole. Gelatin permissible explosives are more suitable than ammonium nitrate permissibles for wet holes, and in general they are stronger and more violent than are the ammonium nitrate types.

All permissible explosives are strong, must be used in relatively small quantities (less than 1-1/2 pounds) per hole to retain their permissibility, give off considerable quantities of poisonous gases on detonation, and, while much safer than black blasting powder or dynamite, must be stored, handled, and used with care or they can be extremely hazardous.

To develop the desired disruptive effect of an explosive, some means must be adopted to "set off", fire, or "detonate" it without killing or maiming the person or persons doing the blasting; several devices or methods are being utilized, all with a view to having this work done as safely and efficiently as possible. There are two general types of these devices or methods of getting explosives into action - igniters and detonators. The former merely convey a flame to the explosive mass and ignite it, while the latter transmit (originally through ignition of a small quantity of a highly explosive substance by an arc, a flame, or spark) a sharp blow that causes the explosive to dissociate or detonate or burn with very great rapidity and in so doing give off highly heated gases in vastly greater volume than the space occupied by the original explosive; this extremely sudden increase in volume acts with great violence and power on adjacent surroundings. Igniters are squibs (plain and electric), fuse, and delay igniters; detonators are blasting caps (plain and electric), delay electric blasting caps, delay electric igniters with caps, and Cordeau Bickford detonating fuse.

The squib is a small-diameter tube of straw or paper filled with a quick-burning powder and having a relatively slow burning "match head" attached to one end; the latter is ignited or lighted by an ordinary match or other flame, and its relatively slow burning allows the person handling the ignition to retire before the fire is communicated to the quick-burning material in the tube. Squibs are by no means either safe or efficient, even though still used to a considerable extent, especially in coal mining. Electric squibs are somewhat similar to ordinary squibs, except that the ignition is accomplished by means of an electric arc; electric squibs are much more satisfactory, from a safety viewpoint, than ordinary squibs.

Fuse (or, as it is sometimes called, "safety fuse") consists of a fine-grained black-powder core covered with cotton, hemp, or jute to form a ropelike material about 3/16 inch in diameter; one end of the fuse is brought in contact with the powder charge or with a detonating "cap", and the other end (usually several feet away from the explosive) is lighted by a flame from a match, open light, or otherwise. The fine-grained black powder burns gradually and somewhat slowly (about 30 to 40 seconds to the linear foot of fuse) until it reaches the explosive (black powder) or the detonating cap (if some form of dynamite is used), giving the blaster time to get in the clear before the main explosion takes place, provided he uses good judgment. Fuse is much safer than squibs, but fuse has its own hazards and must be used with care.

Delay electric igniters usually are a combination of electric igniters and fuse, the latter being lighted by the igniters within the blasting hole, the fuse transmitting the ignition to the explosive at a rate of speed that depends largely upon the length of the fuse. Delay igniters usually are much safer than fuse, particularly for coal-mine use; but they, too, have their hazards, and, in general, delay blasting is by no means safe procedure in coal mining, though standard and relatively safe practice in metal mining and tunneling, provided sensible precautions are taken.

Blasting caps or detonators are metallic cylinders (usually copper) closed at one end, about 3/16 inch in diameter, and usually less than 2 inches in length, partly filled with a small amount of a relatively easily fired or "detonated" compound, the resultant shock or blow when fired being sufficient, when embedded in dynamite, to fire or detonate the dynamite mass. Ordinary blasting caps usually are fired or detonated by the flame of fuse, the end of the latter being inserted into the open end of the detonator or cap and placed in contact with the highly explosive material in the interior of the metallic capsule or cap. Caps are extremely hazardous to handle, as they are likely to be detonated by heat, friction, or a relatively moderate blow; however, they can be handled with relative safety if handled carefully, partial proof of this being in the fact that where they are manufactured and shipped by the thousands daily, accidents are decidedly rare, because the caps at all times are handled with utmost care.

Electric blasting caps are somewhat similar to ordinary caps or detonators, but the cap is fired by electricity, electric wires being so placed in the capsule or cap that when attached to an electric current an arc is formed within the cap, which detonates the sensitive explosive material in the cap.

Delay electric blasting caps or detonators are somewhat similar to ordinary electric blasting caps, except that several time intervals in blasting are obtained by having the electric arc ignite a short piece of fuse or some slow-burning substance before it reaches the highly sensitive detonating material in the capsule or cap. Numerous time-interval delays are obtained, and in general the delay electric blasting caps are relatively safe and effective even in wet holes, though they ought not be used in coal mining if explosions of gas or dust are to be avoided. Delay electric igniters with caps or detonators are a combination of electric igniter and blasting cap, usually with suitable lengths of fuse between to give the desired delay; they have some advantages but are relatively unsafe and certainly should not be used in coal mining.

Cordeau Bickford detonating fuse is a combined fuse and detonator in the form of a lead tube about 1/4 inch in diameter filled throughout its length with a high explosive - trinitrotoluol (TNT). It is fired by fuse and an ordinary detonator or cap or by an electric cap, and when Cordeau is fired it detonates throughout its length (which may be anything up to or over 100 feet) almost instantaneously, the explosion wave traveling at a rate of about 17,500 feet per second. Although somewhat expensive, it is relatively safe to handle and is particularly effective in deep-well drill holes in quarry and similar work, as it detonates simultaneously throughout its length, adding effectiveness to the main body of explosive, which it actuates or detonates. It fires black powder as well as high explosives (dynamite, etc.) and is obtainable in lengths of approximately 500 feet wound on spools.

In the transportation of explosives, the manufacturers and the railroads have set a most excellent example in safety, as is proved by the fact that accidents in rail transportation of explosives were so rare as to have been almost nonexistent in the past decade. The problem of transporting explosives from the railroad car to the users' magazines and from the magazines to the places of use (the mine, quarry, tunnel) is decidedly serious and should be given much more consideration than it usually receives. The Interstate Commerce Commission has issued numerous explicit regulations on the transportation of explosives, probably the most complete being "Regulations for the Transportation of Explosives and Other Dangerous Articles by Freight and Express and in Baggage Service", issued in 1930, with some later additions or revisions, notably those of 1935, entitled "Regulations for the Transportation of Explosives and Other Dangerous Articles on Public Highways by Motor Truck or Other Vehicle", the latter again being under revision in 1938. Users of explosives who transport them by truck would profit by familiarizing themselves with the regulations established by the Interstate Commerce Commission and by being governed by them. Railroad companies formulate and issue their own regulations for the transportation of explosives and other dangerous articles other than explosives, and the restrictions of some of the carriers are drastic in the extreme. The Bureau of Explosives of the American Railway Association has issued much interesting information relating to the transportation of dangerous substances, including explosives of various kinds. The Bureau of Mines and other organizations have also issued information on the transportation of explosives, but much careless explosives-transportation practice is found, not only in mining work but even to a greater extent in other activities in which explosives are used. State laws on transportation of explosives usually are woefully inadequate insofar as safety is concerned; in fact, State laws on this subject usually are almost nonexistent or are phrased so broadly as to be almost meaningless.

The storage of explosives constitutes one of the most important phases in the safe and efficient use of explosives in commercial work, and many of the dangers, inefficiencies, and difficulties connected with the utilization of commercial explosives are due to defects in storage. Here, again, while some large cities have excellent regulations and enforce them, State laws usually are inadequate and enforcement of such laws as are on the statute books is largely a gesture. The explosives manufacturers as well

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as other organizations, however, have tried to take up some of the slack due to the failure of the various States to act at all efficiently; and numerous excellently worded recommendations as to safe and effective storage have been issued. The Institute of Makers of Explosives, 103 Park Avenue, New York City, has published a pamphlet, "Standard Storage Magazines Recommended by the Institute of Makers of Explosives" and has also issued the "American Table of Distances, Specifying Distances to be Maintained Between Storage Magazines for Explosives and Inhabited Buildings, Public Railways, and Public Highways." In addition, the Institute of Makers of Explosives has issued a pamphlet entitled "Suggested State Law Compiled by Institute of Makers of Explosives", and this has been the foundation of the law of at least some States with respect to explosives; the suggested law itself appears to have excellent provisions and it should be productive of good results if enforced with judgment.

Those whose work keeps them in fairly close contact with the utilization of explosives are almost universally of the opinion that conditions of storage determine largely not only the safety but also the efficiency that may be expected when explosives are used. Extremes of heat or cold, of air dryness, or of moisture in storage, the roughness or carefulness with which they are handled, the length of time they are stored, the length of time they are out of their original container before they are used - these and many other considerations have a vital influence on whether a commercial explosive will act as it is supposed to act or will show some of the many idiosyncracies for which it is noted, whether rightly or wrongly.

Not only one but several books could be written in connection with safety in the use of commercial explosives, and numerous fairly compact and reasonably up-to-date publications are available to those who are interested in the subject.

The various manufacturers of explosives issue numerous pamphlets in connection with their several products, and many excellent suggestions are made with respect to the safe and efficient transportation and storage as well as use of explosives; a particularly informative pamphlet is one entitled "Safety in the Handling and Use of Explosives", issued by the Institute of Makers of Explosives, 103 Park Avenue, New York City, this pamphlet having been published under the auspices of at least a dozen of the most representative explosives manufacturing organizations of the United States. It discusses in a terse, clear manner, readily understandable by persons not particularly familiar with explosives technical terms, such subjects as transportation (4 pages), storage (2 pages), transportation from magazine to working face (4-1/2 pages), opening cases of explosives (2-1/2 pages), making and handling primers (6-1/2 pages), loading boreholes (8-1/2 pages), tamping boreholes (1-1/2 pages), firing shots (6 pages), handling misfires (7 pages), organization of operations, selection and education of men, and maintenance of discipline (2-1/2 pages). Four pages of warning "don'ts" (52 items in all) are given at the end of the pamphlet. Included in the pamphlet, also, is a decidedly informative 10 pages devoted to failures of various kinds in connection with commercial explosives listed in one column as to "causes" and in an opposite column as to "means of prevention"; there are six parallel

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items of this kind with regard to "Failures with Miners' Squibs", 28 items on "Failures with Safety Fuse or with Blasting Cap and Fuse", 25 items on "Failures with Electric Blasting Caps and Delay Electric Blasting Caps", 4 items on "Failures with Delay Electric Igniters", and 5 items on "Failures Due to the Explosive." These 10 pages of "causes" of failures of various kinds with companion column of "means of prevention", listing altogether 68 distinct items, are in themselves a bible of information on safety for the user of explosives.

The Bureau of Mines of the United States Department of the Interior has issued much information about the testing, transportation, storage, and use of explosives in the mining and allied industries, but more especially with respect to coal mining. This information has been published in numerous pamphlets (bulletins, technical papers, reports of investigations, and information circulars), many of which are now out of print; among those now available are the following: Bulletin 326, Explosives Accidents in the Anthracite Mines of Pennsylvania 1923-27, issued in 1931; Bulletin 346, Physical Testing of Explosives at the Bureau of Mines Experiment Station, Bruceton, Pa., issued in 1932; Bulletin 349, Liquid Oxygen Explosives, issued in 1932; Technical Paper 567, Preventing Accidents by the Proper Use of Permissible Explosives, issued in 1936; and Report of Investigations 3350, Production of Explosives in the United States during the Calendar Year 1936, issued in 1937. Copies of all of these, except the report of investigations, as well as of numerous other publications, on explosives are obtainable from the Superintendent of Documents, Washington, D. C.; the report of investigations may be obtained from the Bureau of Mines, United States Department of the Interior, Washington, D. C.

Safety in the use of explosives is treated in various pamphlets and other information given out by the National Safety Council, the American Standards Association, and various technical journals, and numerous individual mining and other commercial companies have definite, specific regulations (many of them in printed pamphlet form) with regard to safety in the utilization of explosives.

Certainly one precaution that could and always should be taken in connection with explosives is to have as few persons as possible engaged in handling them or present in the vicinity of the place where explosives are in use. Equally certain is the fact that explosives should not be entrusted to any but careful, intelligent persons, capable of realizing the hazards of explosives and sufficiently well-informed about those hazards to be dependable in carrying out regulations and sane, safe procedure in the handling and use of explosives.

In mining and quarrying, only relatively safe and definitely suitable types of explosives should be used for the work at hand, which means that black blasting powder in all of its forms will be eliminated; only permissible explosives should be used in coal mines; no straight nitroglycerin dynamites should be used underground in metal mines or in other confined places; in underground mines blasting should be done only at the end of the shift or preferably at a time when the working shift is out of the mine;

blasting in coal mines should be entrusted so far as feasible only to such persons as certified shot firers known to be competent to handle explosives carefully and safely; explosives at mining villages should not be kept at company stores, sold to women or children, or kept even over night at any miner's home; explosives should not be stored in coal mines; explosives magazines in metal mines should be in a cool, relatively dry place, several hundred feet from the shaft or other stations where men pass or congregate, and kept under lock and key; it should be realized that all explosives give off poisonous fumes upon detonation or in burning, hence no person should be required or allowed to return to a blasted face or place until the smoke, gases, and dusts from the blast have been removed by ventilation or otherwise. These are only a few of the fundamentals that should be observed in blasting if even a fair degree of safety is to be expected.

This paper of necessity can merely touch upon a fraction of one percent of what can be stated on the subject of the safe transportation, storage, and use of explosives.. Commercial explosives are a vital factor in our present-day civilization, and while many of us who are primarily safety-minded would much like to have eliminated from industrial work so destructive an agency as explosives can be under some circumstances, few, if any, can foresee a time when commercial explosives can be replaced by a less hazardous agency. Knowing that explosives are sure to remain vital in much of the engineering and other work now so important to human beings, it is necessary to accept the inevitable fact that explosives must be used and to try to handle them so that the hazardous character of work with explosives is always recognized and remembered and every feasible safeguard taken to prevent accidents and disasters.

APPENDIX

RECOMMENDATIONS OF COMMITTEE TO THE INDUSTRIAL COMMISSIONER RELATIVE TO CONTROL OF TOXIC GASES AFTER BLASTING IN MINES, TUNNELS, AND SHAFTS

(a) Each case containing explosives for underground use shall be clearly marked in 1/4-inch or larger type with the designation "Fume Class 1", "Fume Class 2", or "Fume Class 3", to indicate the amount of poisonous gases produced. The amount of poisonous gases produced shall be the total volume of carbon monoxide plus hydrogen sulphide emitted in the Bichel gauge by a 1-1/4 x 8 inch cartridge of such explosive as determined by tests according to the standard procedure of the U. S. Bureau of Mines, in which tests the gases emitted shall not contain more oxygen than is sufficient to burn the combustible gases to their maximum oxidizable state. The amount of poisonous gases produced per 1-1/4 x 8 inch cartridge shall be less than 0.16 cubic foot for "Fume Class 1", from 0.16 to 0.33 cubic foot for "Fume Class 2", and from 0.33 to 0.67 cubic foot for "Fume Class 3." Explosives in cartridges smaller than 1-1/4 x 8 inches shall comply with the limits specified for the fume class of the 1-1/4 x 8 inch cartridge of that explosive.
(NOTE: The Standard test procedure of the U. S. Bureau of Mines referred to in paragraphs (a) and (c) of these orders is recorded on pages 91 to 94 of the U. S. Bureau of Mines Bulletin 346, entitled "Physical Testing of Explosives.")

(b) No explosive other than those in "Fume Class 1" shall be used underground in any operation, except that if conditions in any operation warrant, the Commissioner may, at his discretion, grant permission for use of explosives in "Fume Class 2" or "Fume Class 3" when proper application has been made by an operator for such use.

(c) No explosive shall be used underground in any operation if the gases emitted in the Bichel gauge in tests, according to the standard procedure of the U. S. Bureau of Mines, contain more oxygen than is sufficient to burn the combustible gases to their maximum oxidizable state.

(d) No explosive which is packed in cartridges of less than 1 inch diameter shall be used underground in any operation.

(e) No explosive shall be used underground in any operation except in its original wrapper only, i. e., no explosive shall be used with its wrapper removed, and no additional paper shall be wrapped around the explosive charge.

(f) No explosive that has obviously deteriorated due to improper storage, or to any other cause, shall be used underground in any operation.

(g) Permissible explosives used in underground operations having inflammable gas shall conform to all requirements of the United States Bureau of Mines as to permissibility and are therefore excluded from the requirements of Paragraphs (a) and (b) of this order.

(h) No person shall enter a hazardous area created by a blast involving 25 pounds or more of explosives in any underground operation until at least 15 minutes have elapsed after such blast.

(i) No person shall enter with the intention of remaining, or shall remain, in a section containing gases produced by a blast in any underground operation unless the ventilation meets the requirements herein prescribed. The ventilation must be maintained so that in the breathing zone of the section the concentration of carbon monoxide, as determined by a carbon monoxide detector approved by the Department of Labor, does not exceed 0.030 percent by volume at the time of entrance into such section, and does not exceed 0.015 percent at the end of 1 hour after entrance, and 0.010 percent at the end of 2 or more hours thereafter; provided, however, that this regulation is not intended to prevent entering into, passing through, or remaining in localized sections for a period not exceeding 5 minutes in concentrations of carbon monoxide of 0.060 percent to 0.100 percent or for a period not exceeding 15 minutes in concentrations of carbon monoxide of 0.030 percent to 0.060 percent.

When the concentration of carbon monoxide and the conditions of exposure to this gas in a section exceed the limitations stated in the foregoing paragraph, adequate respiratory protection shall be provided and shall be used by any person entering said section.

A contractor or operator shall designate a capable man whose duties it shall be (1) to make such tests and examinations as are necessary to establish conditions with respect to ventilation and poisonous gas concentrations in sections containing such gases from blast from explosives; (2) to direct and control the entrance into and periods of exposure of all persons within such sections; and (3) to keep a dated record of all such tests and examinations, which record shall be available for examination by inspectors of the Department of Labor at all times.

(j) In addition to the foregoing, in any shaft or tunnel of a construction project the minimum amount of fresh air introduced into the shaft or tunnel heading shall be the larger of the two following alternatives: (1) 100 cubic feet per minute per man occupying the section within 200 feet of the blasted face; and (2) 5 cubic feet per minute per cartridge of explosive used in blasting that face.

In all blasts involving delay electric blasting caps in shafts or tunnels, each shot hole must be adequately stemmed with noncombustible material or the explosives confined in some other manner approved by the Industrial Commissioner.

No internal combustion engine shall be used in any shaft or tunnel of a construction project except as same has been approved by the Department of Labor.

A contractor doing work involving shafts or tunnels, the total contract value of which work is $250,000 or more, shall employ a licensed professional engineer whose duty shall be: (1) to make such tests and examinations as are necessary to establish conditions with respect to ventilation and poisonous gas concentrations in sections containing such gases from blasts from explosives; (2) to direct and control the entrance into and periods of exposure of all persons within such sections; and (3) to keep a dated record of all such tests and examinations on a form provided for the purpose by the Department of Labor, to certify same, and mail same monthly to the Department of Labor.

EXPLOSIVES

ORDER 1745. EXPLOSIVES FOR UNDERGROUND USE.
FROM MINE SAFETY ORDERS
CALIFORNIA - INDUSTRIAL ACCIDENT COMMISSION - 1938

(Note - Order 1745 shall not apply to explosives used in coal mines.)

(a) Each case containing explosives for underground use shall be clearly marked with the class that indicates the amount of poisonous gas produced per 1-1/4 x 8 inch cartridge.

(b) For the purposes of this order, the poisonous gas-producing properties of an explosive shall be the volume of carbon monoxide plus hydrogen sulphide emitted by 1-1/4 x 8 inch cartridges as shown by tests in the Bichel gauge according to the standard procedure of the U. S. Bureau of Mines, provided the resulting gases do not contain more oxygen than is sufficient to burn the combustible gases to their maximum oxidizable state.

(c) No explosive shall be used underground if the gases emitted in tests in the Bichel gauge, according to the standard procedure of the U. S. Bureau of Mines, show more oxygen than is sufficient to burn the combustible gases to their maximum oxidizable state.

(d) Cases containing explosives for use underground will be considered clearly marked if they bear in 1/4-inch or larger type the designation "Fume Class 1", or "Fume Class 2", or "Fume Class 3", provided the explosives contained in the cases so marked comply with the following classification:

Cubic feet of carbon monoxide plus hydrogen sulphide per 1-1/4 x 8 inch cartridge when tested according to paragraph (b)

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Fume Class 1 -- Less than 0.16.
Fume Class 2 -- 0.16 to 0.33.
Fume Class 3 -- 0.33 to 0.67.

Explosives in cartridge sizes smaller than 1-1/4 x 8 inch shall not emit more poisonous gases per cartridge than are emitted by 1-1/4 x 8 inch cartridges as defined above.

(e) No explosive shall be used underground in the presence of combustible gases and/or combustible dusts unless specific application is made by the operator to, and the use approved by, the Commission.

(f) Explosives complying with the requirements of Fume Class 1 may be used in underground workings free from combustible gases and/or combustible dusts without specific application by the operator to the Commission, provided the explosive (1) has not deteriorated in prolonged or improper storage, (2) is properly charged and stemmed with noncombustible stemming, (3) does not have a burden so heavy that it will obviously be liable to blow out, (4) is not overloaded, and (5) the mine is properly ventilated as required by Mine Safety Order 1778. Before blasting, the men must be removed a safe distance from the face and shall not return to the face until the poisonous gases have been cleared.

(g) Explosives complying with the requirements of Fume Class 2 and Fume Class 3 shall not be used underground unless the operator has made specific application to, and has shown to the satisfaction of, the Commission that adequate ventilation has been provided and that the operating requirements specified in paragraph (f), (1), (2), (3) and (4), will be met.

(h) All explosives packed in cartridges must be loaded in the original cartridge without alteration of the quantity of the wrapper.